Shot-hole Borer of Tea:

MAGE CAUSED TO THE TEA BUSH.

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DEPARTMENT OF AGRICULTURE, CEYLON.

BULLETIN No. 60

SHOT-HOLE BORER OF TEA.

(*Xyleborus fornicatus* Eich.)

Damage caused to the Tea Bush.

THOUGH the Shot-hole Borer Beetle of Tea has now been recognized as a very serious pest of the tea plant for some fifteen years, the exact damage caused by the insect has never as yet been fully formulated.

The work of excavation in the woody portions of the plant is done entirely by the female beetle, thus confining the subject of this Bulletin to a description of the plant tissues mechanically removed when the gallery of the beetle is being constructed, and of any physical effects which may result from this, or from the growth of the Ambrosia fungus which develops on the walls of the excavations and from which the larvæ obtain their nutriment.

A glance at Fig. I. will give a general idea of the structure of a stem or trunk of a tea plant, which consists of a number of rings of tissues, one within another; *A* shows these in transverse section; *B*, on a smaller scale, in longitudinal section through the middle of a stem; *a*, the outside ring of tissue is the bark or protective layer; *b*, is the bast, which conducts organic matter from the leaves to the stem and roots; *c*, is the cambium, the active ring which constantly renews the bast on the outside and the wood on the inside; *d*, the wood,

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conducts the sap from the roots to the leaves; and *e*, the medullary rays, which run radially from pith to bast, serve as conductors of nutritive substances from wood to bast and *vice versâ*. These do not appear in the longitudinal section B.

f, is the pith, a functionless tissue forming the centre of the stem, derived from old and dead wood tissues for which there is no further use. Excavation of the pith, and isolated holes made through the bark, bast, and cambium could have no appreciable effects upon the plant, and it therefore remains to be seen what mechanical damage is done to the wood vessels, which are the tissues which conduct the sap from root to leaves and to the medullary rays.

Formation of the Gallery.

The female beetle may select for its entrance a spot just below, or just above, the junction of a leaf with the stem the region of a leaf-scar, or of a bud on new "red" wood, the region of an "eye" on recently pruned wood, or any part of the trunk or "collar," sometimes even as much as half an inch below the ground level. The fork of a branch also affords a favourite situation.

It is unusual, in red wood branches to find entrance holes except at the "nodes" and in forks, so that in these they are generally distributed at intervals of not less than 2 inches apart. It is also exceptional to find galleries in twigs of less than 5 millimetres diameter, and though entrances may occur in twigs of as little as 3 millimetres diameter, after boring in, the beetle does not continue the excavation.

Fig. II. represents a most exceptional condition, where a very large number of entrances have been made in a branch which was partially split from the rest of the bush. Such a condition has sometimes also been found in the trunks of young tea bushes growing on poor soil.

When attacking the collar of a bush, a gallery of a tree-like shape is constructed, see Fig. III. This is the type-formation of gallery made by the various species of the genus *Xyleborus*. The entrance passes through the bark, bast, and cambium into a short "entrance gallery," from which branching tunnels are made in a horizontal plane in the wood. The side tunnels are the longest, and are made first; they may be each 2 inches in length. The diameter of the entrance and all the tunnels is practically uniform. The borings are all ejected by the beetle in single strips about 0·6 millimetre long and 0·2 broad. See Fig. IV.

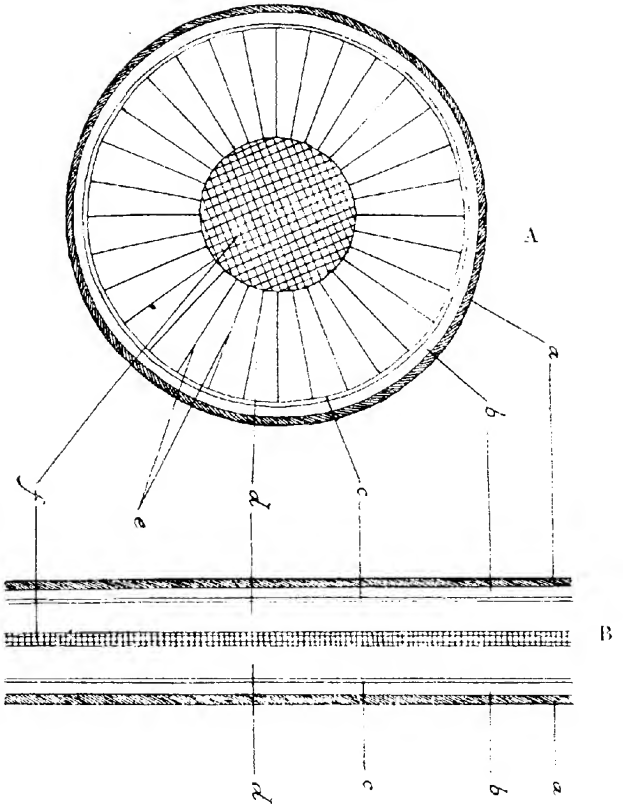

Fig. 1. A. Transverse section through stem; B. Longitudinal sectio through stem.
a Bark; *b* Bast; *c* Cambium; *d* Wood; *e* Medullary Rays; *f* Pith.

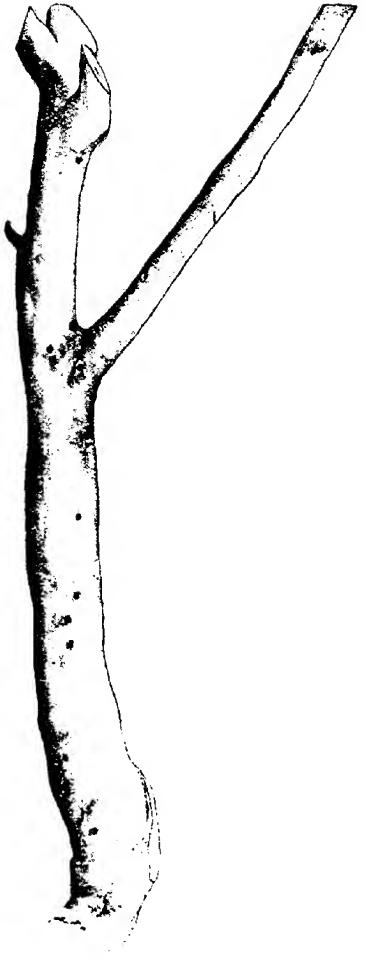

FIG. II. Tea branch showing unusually large number of entrance holes of shot-hole borer.

When working in thinner branches, however, a different procedure is resorted to in order that the horizontal type may be conformed with to as great an extent as is possible.

Such a gallery is represented in Fig. V., this being the type usually found in branches of about 20 millimetres thickness. The entrance (1) leads as before into an entrance "arm" (2), passing either straight through the pith or obliquely to the side in the wood. On reaching the wood of the other side, but stopping well short of the cambial layer, two horizontal arms (3 and 4) are made in opposite directions: one of these circles the stem until it nearly reaches the entrance 1, and the other is usually curled inside the first. Later, arms are made, either originating from the entrance arm (2) or from the junction of the horizontal arms, running vertically up and down the pith (5 and 6).

In Fig. V. the stem is represented as being divided across the entrance and horizontal arms, so that one half of each appears on the upper and lower surfaces.

In thinner stems variations occur (see Fig. VI.); the horizontal and vertical arms may become spiral, as in A, and any single arm may not be made at all.

Or, again, both the horizontal arms may be entirely absent, resulting in two very long vertical arms running up and down the pith, as in B. The vertical arm may sometimes run for a distance in the pith and then become spiral, as in C.

Fig. VI. D, shows a form which is common where the entrance is made in or near the fork of a branch: here spiral arms are made up both branches.

Sometimes also, one of the horizontal arms may actually meet the entrance arm, as indicated in this figure.

Tissues Removed.

Galleries in thin stems, where only the pith is excavated together with a small portion of vascular tissue from the entrance to the pith, are of little concern, but it is readily seen, from the various drawings, that, within the limits of the gallery, a considerable amount of tissue which is vitally important to the plant is removed. Though enough wood tissue is left intact to keep up a flow of nutrient sap to the leaves, the efforts of the cambium to repair the damage are highly liable to cause swellings of the stem, resulting in knots. The cutting of the wood vessels, however, affords ideal conditions for the growth of the Ambrosia fungus and thus for the development of the larvæ. Excess moisture in the wood

during wet seasons drains out of the entrance hole in considerable quantities, a fact which has been tested by cementing glass tubes over entrance holes, and if the entrances are closed up, the amount of liquid is sufficient to kill the inmates of the galleries in a very short space of time. It is evident that one of the duties of the female beetle is to keep the entrance clear, and any obstruction will at once bring the insect to the entrance.

The excavations, then, are destined not to cut off the flow of sap, but to keep the inmates of the galleries continually moist, without excess.

It will be seen later that injury to the medullary rays, though local, has a special significance to the welfare of the larvæ. In thin stems, the pith is placed in closer juxtaposition with the vascular tissues than in thicker ones, so that the tunnels are kept moist naturally. Where nearly all the " nodes " of a stem are attacked, the decrease of sap-flow to the leaves must necessarily be considerable, and it is impossible that the flushing capacities of a bush should not be limited to a certain extent, at any rate, when the insect is very prevalent, although the mechanical removal of tissues is but local.

To sum up, it may be stated that the mechanical injuries resulting from excavation by the beetle are confined practically to the tissues of the wood, that portion of the plant anatomy which is concerned with the conduction of simple chemical salts dissolved in water from the roots to the leaves, where these salts are elaborated with organic compounds, and pass down again in the bast vessels. The external manifestation of this is displayed in the formation of knots in the branches, due to general reaction of the plant tissues to internal injury.

The Breaking of Branches.

The hollowing out of circular and to a less extent, spiral tunnels, in the branches causes considerable breakage, especially in localities exposed to wind and in the dry seasons. When thus broken, the fractured ends present a very typical appearance, as shown in Fig. VII. Here, a horizontal tunnel and a vertical tunnel in the pith are exposed.

This breakage takes place usually in fields which are nearing the time for pruning, and it is therefore considered that the loss from this cause is not very great, although it must be remembered that the destruction of a vigorous branch in full flush must reduce the flushing surface of an individual bush to

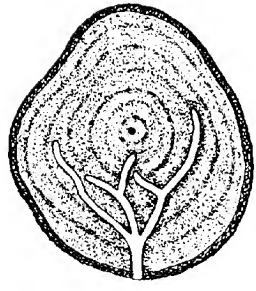

FIG. III.—Tree-like gallery in collar of tea bush.

FIG. IV.—Wood-shaving ejected by beetle during excavation of gallery. × 80.

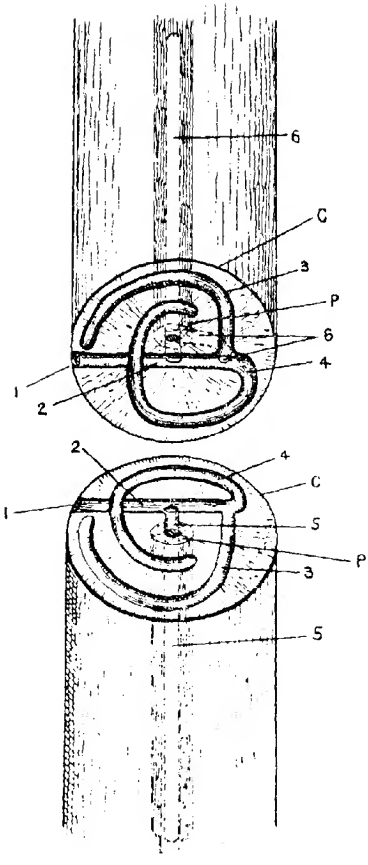

FIG. V.—Tea stem divided across the entrance and horizontal "arms" of gallery. C, Cambium; P, Pith; 1, Entrance; 2, Entrance "arm"; 3 and 4, Horizontal arms; 5 and 6, Vertical arms.

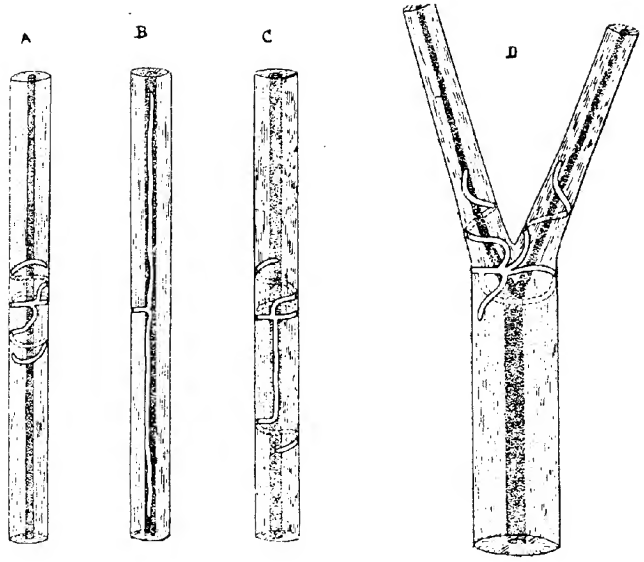

FIG. VI.—Semidiagrammatic representations of variations in gallery. See page 3.

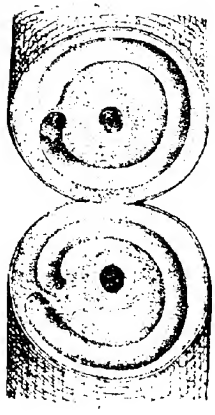

FIG. VII.—Broken tea branch exposing a horizontal and vertical tunnel.

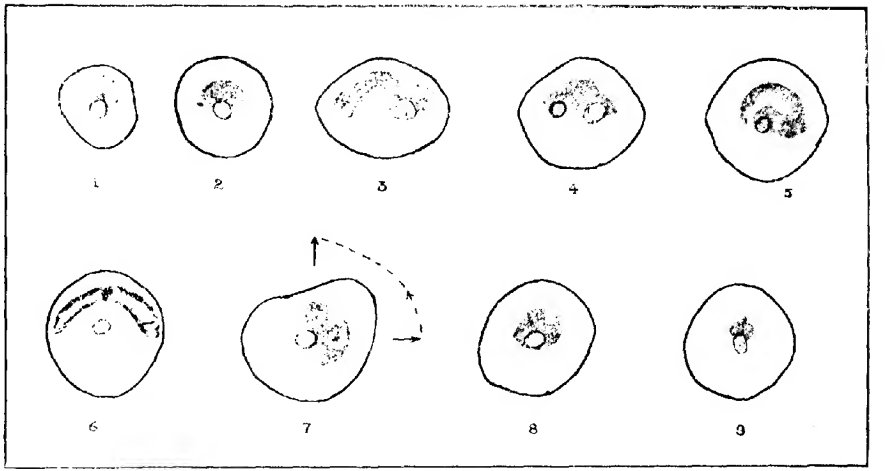

FIG. VIII. Cross-sections of tea stem containing a single gallery of shot-hole borer. The shading shows wood stains, which leave a blue impress on Neutral litmus paper. Nos. 1 and 2, 3 inches above gallery; Nos. 3 and 4, 1 inch above gallery; No. 5, ½ inch above gallery; No. 6, section through the gallery; Nos. 7 to 9, 2 to 5 inches below gallery. Sections 3 and 4 show the stain in a side branch entering the main stem.

no small extent. On the other hand, it is remarkable that these attacked stems do not break more easily under natural conditions, as the light sweeping of the arm over a bush in very badly infected fields is sufficient to fracture practically every branch.

Most serious loss from this cause, however, takes place in young tea coming into bearing. Given a bad attack and a strong wind after the process of " centering," the breakage at different levels renders it almost impossible to obtain well shaped bushes, and the effects remain evident for a number of years after the tea field has come into bearing.

Physiological Damage.

It is quite natural that a disturbance in the tissues surrounding the tunnels hollowed out by the borer should take place. The first reaction which takes place, even before the insect has completed the gallery, is the gradual appearance of a dark purple stain, which ascends and descends above and below the actual gallery, and may be apparent for a total distance of some 8 inches in the stem. This stain gives an appreciable alkaline reaction to litmus paper, and dissolves readily in caustic soda, yielding a dye somewhat resembling Hæmatoxylin. Examined in sections microscopically it is seen that the stain is primarily formed entirely in the medullary rays of the stem, the cells of which are dark brown and opaque.

Fig. VIII. represents a series of sections showing that this stain can be elaborated in a side branch, not actually attacked by the insect.

Fig. IX. shows two sections, A, above the point of entrance to the gallery, and B, through the entrance and horizontal tunnel, from which it is clear that the stain follows the outline of the boring. Whether this stain is due to actual damage to the meduallary rays, or whether it is a deposit following upon the holding up of organic matter from the bast vessels, which should pass to the injured wood-tissues, it is not possible to go into here. After the Ambrosia fungus has been established and the larvæ are feeding, minute amorphous crystals appear in the wood vessels surrounding the tunnels. If acetic acid is applied to sections through the gallery, an effervescence takes place and the crystals dissolve, showing that they are composed of a carbonate, probably of calcium.

The results of these physiological changes in the tissue are not serious as far as the upper branches of a bush are concerned, but in the thicker branches and collar, which remain

after pruning, the stained area decays entirely, where the attack has been of long standing. These decayed portions and branches are subsequently attacked by termites, and finally a total loss of the "frame," which has taken years to build up, is sustained. See Fig. X. The loss of "frame" can only be mitigated by high cultivation which doubtless enables the plant tissues to counteract the extension of this "stain" before decay sets in.

Die-backs.

Though it has been stated that the bast and cambium of the stem are not injured to an appreciable extent, it often happens that the "eyes" or latent buds are directly pierced by the entrance hole of the beetle on branches, shortly before or after pruning. The disturbance of the tissues is such, that similar results may obtain from a boring made, at any place in the region of an "eye." The result is usually a "die-back," in the majority of cases, of the whole branch below the level of pruning. Fig. XI. represents one of these die-back branches with one entrance through an eye and another in the region of an eye. This branch was cut, with many others in a similar condition, from bushes which had been pruned two months previously, and on which the shoots upon the other branches were some 6 inches long, with well expanded leaves. The tissues of these die-backs may remain alive for months, but it is very seldom that they make a good recovery.

Though die-backs occur upon bushes in uninfected fields from different causes, there can be no question that they are vastly increased where the borer is prevalent, and, further, the borer breeds in them for periods varying from one month to four months, according to elevation above sea level, when other branches with shoots will successfully resist attack.

Several records have been taken which amply prove this to be the case :—

Uva.

Elevation : 3,000 feet. Field pruned : July, 1915.
Examined : October, 1915. Period : 3 to 4 months.
Branches with shoots. Of 13 galleries, 12 contained no living insects. One contained 6 males only.
Branches without shoots. Of 6 galleries, 4 contained 11 living insects. One, 2 dead insects, and 1 was empty.

From another field similarly pruned at the same elevation three branches with shoots contained 12 galleries. Of these, 7 had healed over and were empty, 1 was he aled over and contained a dead beetle in a recently started tunne l, 4 were empty.

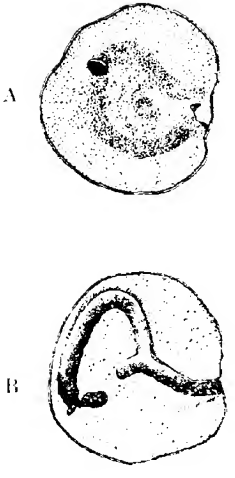

FIG. IX.—Sections of branch; A, above the gallery entrance, and B, through the entrance and horizontal tunnel. The stain follows the outline of the boring.

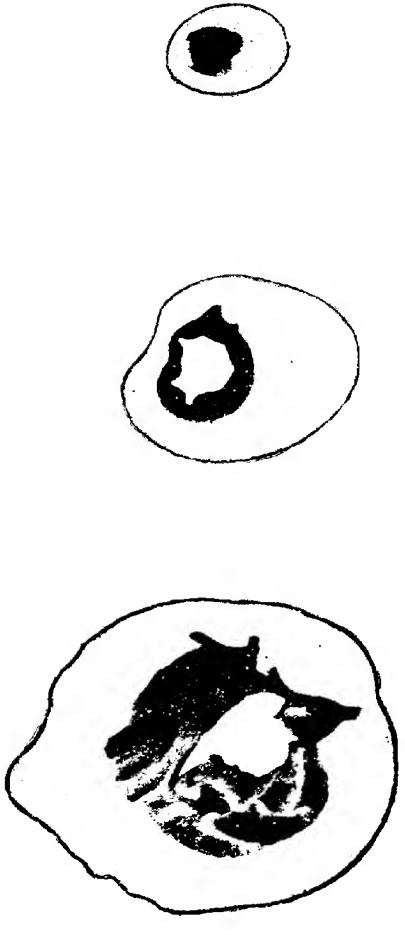

FIG. X. -Sections of stem showing stained area which has decayed and has been attacked by termites.

Two branches without shoots contained several recently vacated galleries, and 2 galleries containing 12 insects.

Southern Province.

Elevation: 200 feet. Field pruned: October, 1915.
Examined: December, 1915. Period: 2 months.

From a single bush :—

5 branches with shoots contained 3 empty galleries healed over.
5 branches without shoots contained 5 galleries with living insects and 7 empty galleries.

From a single bush :—

31 branches with shoots contained 6 galleries in process of construction each with a single female beetle, 1 gallery with larvæ, 21 empty, and 3 healed over containing dead insects.
3 branches without shoots contained 2 galleries with living insects, and 8 empty galleries.

In the last instance it is seen that a number of beetles were constructing galleries in the branches with new shoots, but experience shows that in these branches the beetles are forced to leave before depositing their eggs, the criterion in these examples being the presence of young stages in the galleries.

This leads us to the question of the healing over of entrance holes made by the insect by the plant tissues.

Healing of Galleries.

If a number of branches infected with borer are split down the middle, it almost invariably occurs that a gallery is found which has no entrance hole leading to the exterior. Though these " occluded " galleries have usually been vacated by the inmates, dead insects are often found in them, showing that the entrance has healed over while the insects are still inside. This healing is more noticeable in the wet seasons and in highly cultivated tea, and most of all in tea which has been pruned recently and is ready for " tipping." Except in the case of very poor bushes, it is probable that all entrance holes below the level of pruning eventually heal over after the broods of insects have emerged, but this does not necessarily prevent decay of the tissues within the wood.

Normally, at any rate, injury to the tissues is sufficient to prevent healing as long as the insects are developing in the gallery. In well cultivated tea, even if the collars are riddled with holes, these will disappear almost entirely four months

after pruning. It has been shown, further, in the Bulletin on the treatment of prunings, that healing can take place in branches cut from the bushes and buried beneath the ground.

The active cambium layer is responsible for this. The plant cells of this "layer", are concerned in repairing bast and wood and continually adding to them. It is therefore quite natural that this should happen, where a borer has entered.

The cambium cells, then, multiply round the entrance hole and a wad of tissue results, which grows further and further into the tunnel, until finally the whole gallery may be filled up. The beginning of this wad of tissue, known as a "Callus," is shown in the transverse section Fig. XII.

A similar callus may be formed when the extremities of the horizontal gallery-arms approach the cambium from the inside of the stem. When an incomplete gallery containing insects is about to heal, evidence is shown that the drainage of the tunnel is impaired. A considerable pressure of liquid, in which the inmates are drowned, forces decaying larvæ, and "pellets" of fungus, teaming with bacteria, through the entrance, a condition which can be produced artificially by covering the entrance holes with a thick rosin mixture. When the foul-smelling exudation has ceased, the formation of a "callus" proceeds.

Where the vigour of the cambial layer is sufficient to heal over a tunnel in process of construction, containing a single female beetle, the insect may sometimes have time to leave the tunnel, but often is entrapped and being unable to turn round in the tunnel, so as to force the entrance with its mandibles, dies within it.

It is curious that the beetles are not endowed with the facility for boring their way out when the entrance heals, but not one single case of an "exit" hole has yet been observed. It seems probable that the instinct of emerging by way of the entrance hole is so prominent, that the meeting of a contingency of this nature is not possible.

When a gallery has been vacated naturally by the brood of the borer, the walls of the tunnels turn a deep black colour. but when the beetle is forced to leave while the brood is still developing, the tunnels present a fresh appearance, in spite of any wood staining which may occur. In rare instances of entry into dead wood. no stain appears in the tissues.

The healing of galleries is the only known natural control exercised upon the insect; it is a true example of "plant resistance," which is induced by vigorous sap-flow, in wet seasons, and after pruning, when the new shoots are evoking rapid sap ascent and the vigorous formation of organic food materials.

FIG. XI.—A die-back branch with two shot-hole borer entrances, the lower entrance passing through an eye and the upper in the region of an "eye."

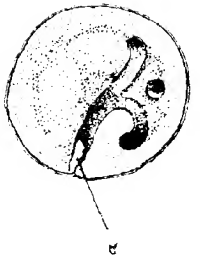

FIG. XII.—Section through gallery at the point of entrance showing ingrowth from cambium. *a*

Liability of Bushes to Re-attack.

When the investigation into Shot-hole Borer Beetle was started, early in 1915, it was observed that individual bushes and patches of bushes in fields were often severely infested, while the surrounding bushes were practically free from the borer. This led to an idea that the attacked bushes might well be in a condition to invite further infestation from insects visiting them, more readily than bushes which were previously unattacked.

Accordingly, an experiment was carried out upon a plot of tea in Uva at an elevation of about 2,500 feet.

The plot chosen contained 257 bushes, which had run twenty-one months from the previous pruning, on fairly level ground and giving a good average yield.

The bushes were surrounded on all sides by infested tea.

The method of procedure was to remove all infested branches at intervals of two or three weeks, and note what bushes were attacked in the intervening periods. Fortunately, the collars of these bushes were attacked to a very small extent, and any holes found in them were stopped up with wood splinters or small nails.

On April 24, 1915, 93 bushes were found to be attacked, and the attacked branches were removed.

On May 8, fourteen days after, 77 bushes were attacked, of which 58 had been infested previously: 19 new bushes were attacked. The infested branches were again removed.

The subsequent results are best seen from the table here given:—

1	2	3	4	5				6
Period.	Duration: days.	Total Bushes attacked.	Bushes not attacked previously.	Bushes attacked previously.				Rainfall.
				Once.	Twice.	Thrice	Four times.	
								In.
To April 24, 1915 ..	—	93	—	—	—	—	—	—
I.—April 4 to May 8 ..	14	77	19	58	—	—	—	—
II.—May 8 to May 28..	21	70	16	23	31	—	—	2·98
III.—May 28 to June 18	21	61	15	15	16	15	—	1·35
IV.—June 18 to July 1	14	65	9	16	19	13	8	—

It is seen that in each period the number of newly attacked bushes (column 4) is very small as compared with those attacked previously and re-attacked in that period (column 5), and as many as 8 bushes, out of the original 93 infested at the start, were re-infested at each successive period. A second and similar experiment was carried out at an elevation of 4,000 feet on younger tea. A row of 41 bushes was chosen on poor, exposed, and sloping soil. The bushes had run only eleven months from the previous pruning :—

1	2	3	4	5					6
Period.	Duration : Days.	Total Bushes attacked.	Bushes not attacked previously.	Bushes attacked previously.					
				Once.	Twice.	Thrice.	Four times.	Five times.	Rainfall.
									In.
To July 12, 1915 ..	—	10	—	—	—	—	—	—	—
I.—July 12 to July 20	8	9	3	6	—	—	—	—	—
II.—July 20 to July 28	8	11	5	2	4	—	—	—	5·00
III.—July 28 to August 8 ..	10	6	3	0	1	2	—	—	4·15
IV.—August 8 to October 14 ..	37	13	6	4	1	1	1	—	6·11
V.—October 14 to October 30 ..	16	7	0	5	2	0	0	0	9·33

The figures here are much the same as those in the first experiment. It is apparent that some bushes, after running for a certain period from pruning, become liable to attack sooner than others, and these may be infested several times before neighbouring bushes, which do not show this liability till later.

The reason for this "immunity," which is doubtless influenced to some extent by cultivation and quality of soil, is not definable, but some light is thrown upon it when the effects of pruning are taken into consideration.

Effects of Pruning.

The leaves of a plant are entrusted with the functions of respiration, and of elaborating the salts in solution carried to

them in the upward flow of sap from the roots, with the carbon dioxide of the atmosphere, to form organic compounds which pass downwards again to the roots.

Where pruning takes place, and the leaves are removed, the downward sap-flow ceases, and a corresponding cessation of the upward sap-flow from the roots takes place.

It is often thought that a concentration of sap takes place in the bush after pruning, but this concentration is entirely temporary, and lasts but a short time.

The concentration takes place where the new shoots have appeared. It is thus seen that the healing of borer galleries is most prevalent after the new shoots appear, and during the one or two months following pruning, the tea bush is highly liable to attack by the insect.

In conjunction with the experiment described above, the effect of pruning an adjoining row of tea bushes, 41 in number was tried. Galleries in the collar and branches were carefully counted below the level of pruning, at each period of examination, and any new entrances duly noted. The table shows the results :—

1	2	3	4	5					6
Period.	Duration : Days.	Total bushes attacked.	Bushes not attached previously.	Bushes attacked previously					Rainfall.
				Once.	Twice.	Thrice.	Four times.	Five times.	
									In.
To July 12 ..	—	11	—	—	—	—	—	—	—
I.—July 12 to July 20	8	7	3	4	—	—	—	—	—
II.—July 20 to July 28	8	7	7	0	0	—	—	—	5·0
III.—July 28 to August 8 ..	10	12	10	1	1	0	—	—	4·15
IV.—August 8 to October 14 ..	37	5	2	3	0	0	0	—	6·11
V.—October 14 to October 30 ..	16	2	0	2	0	0	0	0	9·33

A month after the last period, the bushes were found to be free of infestation, the entrance holes having healed over in all the previously attacked bushes.

The fact that the galleries in the experiment were not removed to a certain extent precludes the possibility of comparing

them with the previous experiment, but it is obvious that, after the first period, the figures of columns 4 and 5 are practically reversed.

Most important, however, is the fact that, after the third period, there is a marked falling off in the number of bushes attacked and this diminution corresponded exactly with the appearance of the new shoots.

It is only necessary to examine a field which has been pruned from four to six months previously, and which was attacked fairly badly before pruning, to confirm the conclusions of this experiment, namely, that the appearance of new shoots on the bushes coincides with a healing of the galleries left below the level of pruning, and renders the bushes temporarily immune to attack until the new branches are matured, and have formed new red wood suitable for the beetle to breed in.

Fields which are run three years between pruning appear to keep this immunity for longer periods than those pruned at shorter intervals, and the same applies to fields run for two years as compared with those run only eighteen months and less.

It is not, however, recommended that any tea be run for a longer time than is consistent with obtaining a profitable yield to the estate, as the natural control of the borer through pruning is purely temporary.

A control scheme was based upon this immunity after pruning, and carried out on fields of two estates, respectively 30 and 22 acres in extent. To be carried out with any hope of success, this scheme would probably have to be made a universal estate practice, and as it involves a considerable amount of labour, it has given way to more practical methods.

The Effect of Slashing and Cutting Across.

Although a true pruning, whether heavy or light, tends to put a check upon the increase of borer, methods of "slashing" and "cutting across" do the very opposite. It has long been a practice to slash tea to bring the bushes into bearing, and sometimes old tea is similarly slashed, in cases where it ceases flushing before the appointed time of pruning, with a view to obtaining a crop for an extra month or two.

Slashed tea, whether young or old, affords a breeding ground especially favourable to borer, and vast differences have been noted in the extent of attack between unslashed

and slashed bushes even standing in the closest proximity to one another. By this method, the surface of respiration and transpiration through the leaves is considerably reduced, and a corresponding reduction takes place in the flow of sap from the root, while the surface of attack open to the borer is no way reduced. Further, the new flush resulting is taken by the plucker, so that the bush is kept in a continuous low state of vigour until proper pruning takes place. It is therefore recommended that all methods of "slashing" and "cutting across" be avoided as far as possible, and that young tea be allowed to run up for an extra period of time and then pruned down prior to the first tipping.

Loss of Crop and Damage to Frame.

It would be most misleading to give figures showing loss of crop from Shot-hole Borer. The actual mechanical damage in the wood of branches is evidence that crop is lost, but there exists always a series of other factors which tend to hide this loss, such as rainfall, quality of soil, application of manure, and general estate conditions. From observation on estates or fields which have recently been attacked for the first time, it would appear that a loss of crop takes place just prior to a marked increase of the insect, and it is possible that this is the case in certain plots at the Peradeniya Experiment Station. Here there are two dadap-covered tea plots, both of which have lately shown a marked decrease in crop after having given abnormally high yields.

In one of these (No. 149) where Shot-hole Borer has existed for years, the attack increased greatly when, and possibly after, the crop fell off, while the other plot (No. 144) has shown a similar decrease of crop, and is still only slightly attacked. The Albizzia plot (No. 150) was, in January, 1918, just prior to pruning more severely attacked than ever previously, but the decline in yield is attributable more to climate than to borer. Shot-hole Borer most probably appeared on the Allagolla Estate, Uda Pussellawa, for the first time in field X, during the south-west monsoon of 1918, and from this, field IX., was infected later in the year. In both fields only a few bushes were infected, and no loss of crop could possibly have resulted from the insect in either field; yet the crop has fallen far below the average in 1918 as compared with the four preceding years.

Field 26 A of the Craighead Estate, Nawalapitiya, was the first locality in which Shot-hole Borer was noticed in Ceylon

as a pest. Writing in July, 1909, to Mr. E. E. Green, Mr. George Alston says: "I first noticed this pest on Craighead in January, 1892, in Field 26 A . . . . . I have the returns by me of the field which was first attacked from 1895 onwards. The tea in question was planted in patana in the north-east of 1887. I have not the returns previous to 1895, but the yield was not greater. I think it was first manured in 1894. Jât is only fair and it was very cheaply planted." The yields given are represented graphically together with those from the two Allagolla fields, and from plots 144, 149, and 150 of the Experiment Station, Peradeniya.*

In all cases here, the loss of crop from borer, if any, has been rendered undeterminable by climatic conditions and by the application of manure, and on Allagolla and at Peradeniya the decrease of crop seems rather to have influenced the increase of borer than *vice versâ*.

To the ordinary observer, an infested tea field in full flush presents little, if any, difference in appearance from one in which the borer is entirely absent.

In his Circular of December, 1903, Mr. Green says: "During the rainy seasons, or even at any time except one of drought, there is little outward indication of the presence of the pest. Given otherwise favourable conditions, it is astonishing to see how freely even a badly riddled bush will continue flushing. But let some weeks of dry weather occur, and a general yellowing of the foliage and premature cessation of flush will suggest some hidden disease. These symptoms are naturally more marked on poor soil, but the borer itself does not specially attack weakly tea. It is equally at home in well grown bushes. The tea "shuts up" completely and pruning is called for."

During the past two years, special opportunities have been afforded for a verification of these "symptoms" by long spells of drought which have occurred, and it has been possible to make a comparison between the general appearance of badly infected fields with that of fields with little or no borer in the same district and under very similar conditions.

Mr. Green was not only most accurate and detailed in his Entomological researches, but was also a planter for a considerable number of years; in this case, however, it is necessary to differ from his opinion, and to state with some confidence that the yellowing of the foliage is due entirely to prevailing climatic conditions, and that the only general

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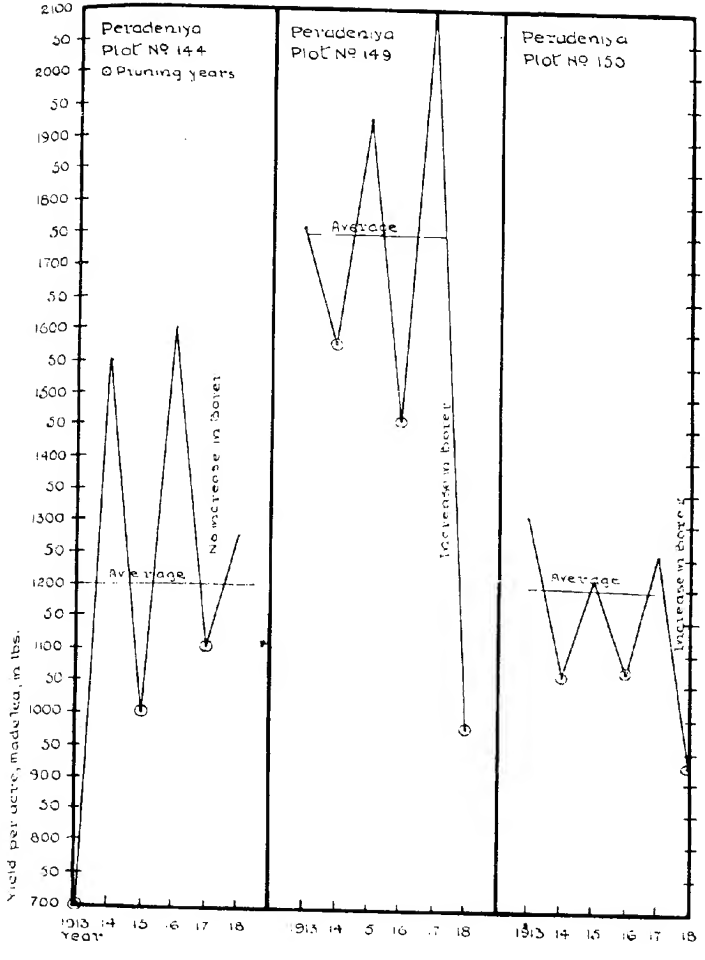
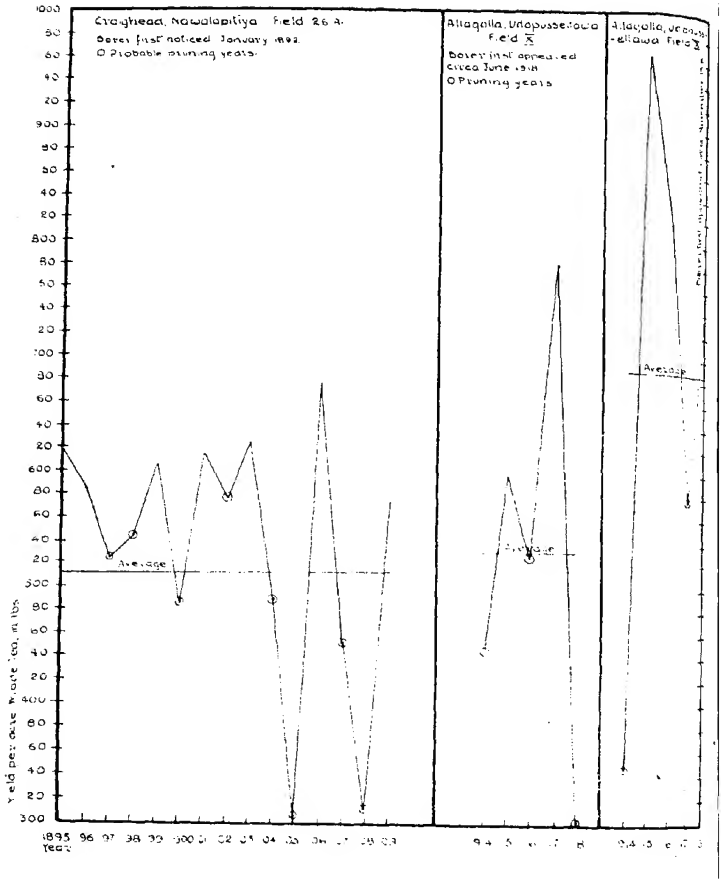
* See Graphs 1 and 2.



Graph 1. See page 13.



Graph 2. See pages 13 and 14.

manifestation of the presence of borer is shown by an increased number of die-backs in fields shortly after pruning, in the presence of broken branches in young and in flushing tea, usually shortly before pruning, and in the knotty, atrophied appearance of the frames of the bushes, resulting in the subsequent growth of "whippy" branches.

When borer has been at work for a number of years, indeed, the loss of frame must lead to a definite pecuniary loss to an estate, upon which care has been taken and extra money expended upon good pruning.

Conclusions.

Though any actual figure to prove loss of crop from Shot-hole Borer are admittedly not forthcoming, the general damage to the frame and the loss of branches through die-back is considerable.

Control measures are thereby called for, and the information given in this Bulletin leads to some suggestions which may be made for such a control.

At every pruning, provided that the wood of the pruning is burnt, a large number of beetles and larvæ are destroyed, and the natural immunity of bushes to attack at the appearance of new shoots exercises some temporary check upon the insect.

The most suitable time for control measures falls at those periods between the time of pruning and the appearance of the new shoots, and at such intervals between prunings as labour is available on estates.

With regard to the former proposition, it has been recommended that die-backs and non-shooting branches be cut from the bushes and burnt at periods varying from one to four months after pruning in accordance with elevation. This, however, does not provide of any means of preventing the escape of vast numbers of insects immediately after pruning to other fields in full flush. The fact that, to the female beetle is entrusted the function of keeping the entrance hole clear of obstructions and of regulating the drainage in the gallery which she has constructed, suggests the use of a powerful insecticide at the time of pruning. The insecticide also exercises a deterrent effect, thus preventing young adult beetles from excavating fresh galleries, at any rate temporarily, in the bush below the level of pruning. The parent female killed or forced to leave the gallery, the drainage system breaks down, and any eggs or larvæ. and probably

even pupæ perish. Thus a great source of infection is cut off and the somewhat laborious procedure of cutting off die-backs, though practical, will probably be avoidable. In flushing tea, the breaking of branches when bent down, indicates the presence of borer, and if these branches are cut out and destroyed at a suitably early time after pruning, a time which must vary with elevation, severity of attack, and extent of cultivation, a further control cannot but result. This will also apply to young tea, combined with the avoidance of "slashing" methods.

E. R. SPEYER.